International Cartographic Association
Association Cartographique Internationale

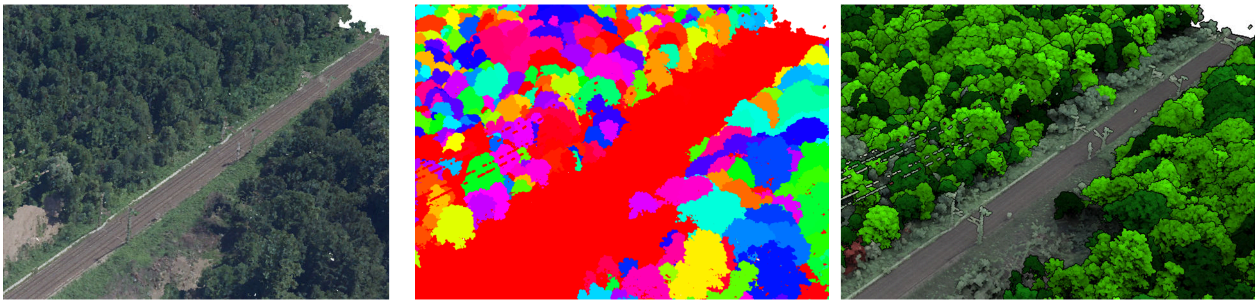
Non-Photorealistic Rendering of 3D Point Clouds for Cartographic Visualization

Ole Wegen[a,*], Jürgen Döllner[a], Ronja Wagner[a], Daniel Limberger[a], Rico Richter[a], Matthias Trapp[a]

[a] *Hasso Plattner Institute, University of Potsdam, Germany - ole.wegen@hpi.uni-potsdam.de, juergen.doellner@hpi.uni-potsdam.de, ronja.wagner@student.hpi.uni-potsdam.de, daniel limberger@hpi.uni-potsdam.de, rico.richter@hpi.uni-potsdam.de, matthias.trapp@hpi.uni-potsdam.de*

* Corresponding author

Keywords: Cartographic visualization, 3D point clouds, non-photorealistic rendering



(a) (b) (c)

Figure 1. Rendering of a given raw 3D point cloud (a) . After tree instance detection and clustering (b), NPR is used to improve perception of semantic classes and tree instances (c).

We present an approach for real-time non-photorealistic rendering (NPR) of 3D point clouds that provides a general-purpose component for their cartographic visualization. For a given 3D point cloud, per-point attributes are derived in the preprocessing phase, e.g., for geometric, semantic, and instance information. The point cloud thus attributed is then segmented into point clusters according to thematic or semantic criteria. Different NPR styles configured by style descriptors can be bound to this information, i.e., the NPR style is parameterized by the point attributes found in the clusters. The approach demonstrates that NPR applied to an enriched, clustered point cloud enables a generalized, abstract, and graphically styled visualization without the need to derive intermediate 3D representations. We have implemented, as a proof-of-concept, several styles and mappings typically required for cartographic 3D visualizations. Figure 1 shows an example of tree detection and its NPR depiction.

3D point clouds have become one of the de-facto standards for 3D spatial models of sites, buildings, and environments; rapid advances in 3D acquisition technologies, including 3D scanners, 3D sensors, LiDAR, RGB-D cameras, and image-based 3D reconstruction, provide 3D point cloud data with increasing detail and resolution in increasingly time and cost efficient ways [Guo 2020]. Point clouds are key spatial data sources in a large number of application domains such as cultural heritage preservation, city planning, facility management, infrastructure monitoring, environmental monitoring, or vegetation condition observation.

As unstructured collections of 3D points, their general characteristics include varying spatial density, high data volume, noise, and incomplete coverage of spatial areas. A raw point cloud does not contain any structural or semantic information. Deep learning on 3D point clouds –still in its early stage– is already being successfully used for 3D shape classification, object detection, object tracking, and point cloud segmentation. Based on deep learning and heuristics-based approaches, we can compute such information and include it as per-point attributes, resulting in enriched point clouds. In particular, point cloud segmentation is important to structure the point cloud into clusters that serve as chunks for NPR-based rendering, since a particular rendering style usually applies to a chunk as a whole.

In general, point-oriented rendering techniques are at the core of implementations of point cloud visualization. For example, the direct rendering of points expands them to small splats or discs positioned in a computed local tangent plane. This way, a photorealistic visualization, textured by RGB photographic data, can be effectively achieved even in real-time; for massive amounts of point cloud data, corresponding level-of-detail approaches are required. In our approach, we investigate non-photorealistic rendering, which concentrates on using abstraction, stylization, and

https://doi.org/10.5194/ica-abs-5-161-2022 |

generalization. NPR is ideally suited to implement the requirements of cartographic visualization, e.g., to highlight or emphasize objects or structures, to express uncertainty, or to sketch 3D models. In this way, cartographic visualization techniques can be implemented that do not rely on rendering intermediate 3D models derived from point clouds, but work directly on pre-processed point clouds.

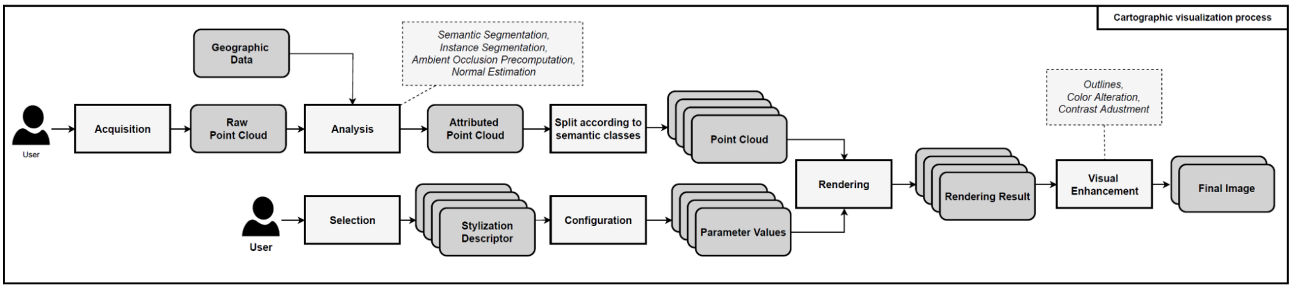
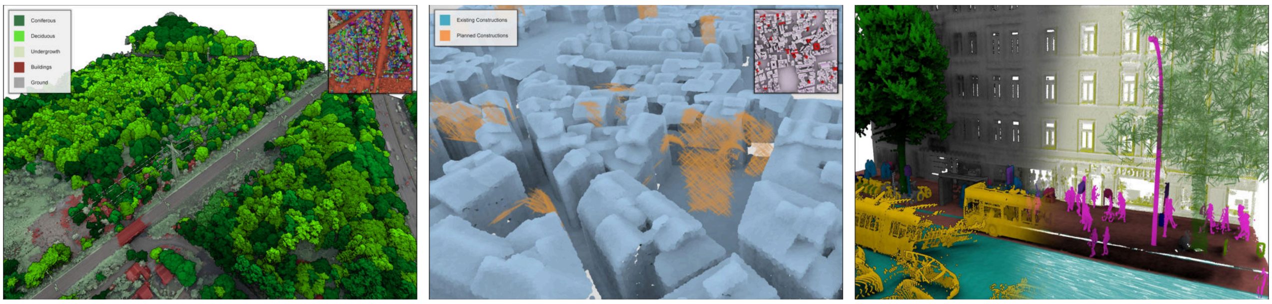


Figure 2. Data (gray boxes) and processes (white boxes) of the implemented cartographic visualization pipeline.

In the visualization pipeline of our approach (Figure 2), raw point cloud data is loaded together with georeferenced data. Next, point cloud analysis techniques derive information such as semantic-based or instance-based segmentations, data relevant for global illumination, and local surface orientation as well as corresponding normals. This information is stored as per-point attributes. Next, the whole point cloud is split into a number of point cloud chunks according to these per-point attributes (e.g., semantic class). To each chunk instance or class, an NPR technique can be assigned as a rendering unit. Each NPR technique is controlled and parameterized by its stylization description (similar to styled layer descriptors used for map appearance description) as well as by the per-point attributes. The per-chunk rendering results are merged into the final image after applying techniques to enhance visual perception, such as color adjustment or outline visualization. Figure 3 shows application examples for the described method.



(a) (b) (c)

Figure 3. Application examples for non-photorealistic rendering of point clouds for cartography. a) Visualization of semantic classes and tree instances using different colors and outlining. b) Visualization of changes to existing structures using a hatching approach [Wagner 2021]. c) A focus and context technique. The left side of the image shows a visualization using separate colors per semantic class. The right side of the images depicts the same data after another stylization descriptor was chosen, designed for enhancing perception of pedestrians. These are rendered with saturated colors, while the rest of the scene is rendered using either unobtrusive colors, transparency, or hatching.

In summary, our work shows how 3D point clouds can be visualized directly by NPR techniques that use point attributes and segmentation of the point cloud into rendering chunks. Since no intermediate 3D representations are required, the original point cloud information remains fully available for the visualization process. The challenges associated with sparse point clouds or missing mesh topology and geometry are addressed for visualization by NPR techniques such as hatching or outlining.

References

Guo, Y., Wang, H., Hu, Q., Liu, H., Liu, L., Bennamoun, M., 2021 Deep Learning for 3D Point Clouds: A Survey. In: *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 43, pp. 4338-4364.

Wagner, R., Wegen, O., Limberger, D., Döllner, J., Trapp, M., 2022. A Non-Photorealistic Rendering Technique for Art-directed Hatching of 3D Point Clouds. In: *Proc., 17th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications*, pp. 220-227.

Abstracts of the International Cartographic Association, 5, 2022.
European Cartographic Conference – EuroCarto 2022, 19–21 September 2022, TU Wien, Vienna, Austria.
https://doi.org/10.5194/ica-abs-5-161-2022 |